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Quarterly Technical Summary

General Research

15 May 1969

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Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts

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INTRODUCTION

This Quarterly Technical Summary covers the period from 1 February through 30 April 1969. It consolidates the reports of Division 2 (Data Systems), Division 4 (Radar), Division 5 (Optics), Division 7 (Engineering), and Division 8 (Solid State) on the General Research Program at Lincoln Laboratory.

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

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DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 February through 30 April 1969 for the General Research Program of Division 2. Separate progress reports on Graphics and Seismic Discrimination describe other work in the Division.

F. C. Frick
Head, Division 2

M. A. Herlin
Associate Head

DIVISION 2 REPORTS ON GENERAL RESEARCH

15 February through 15 May 1969

PUBLISHED REPORTS

Journal Articles*

JA No.			
3211	Methods for Improving the Signal-to-Noise Ratio of Photon and Electron Beam Accessed Magnetic-Film Memory Systems	D.O. Smith	IEEE Trans. Magnetics MAG-4, 634 (1968)
3278	Thin Films. Part I: Introduction Part II: Magnetization Ripple Part III: Uniaxial Anisotropy	M.S. Cohen K.J. Harte D.O. Smith	Magnetism and Magnetic Materials 1968 Digest (Academic Press, New York, 1968)
3283	Feasibility of Lorentz Readout of a High-Density Fast Magnetic Memory	M.S. Cohen	IEEE Trans. Magnetics MAG-4, 639 (1968)
3287	Scattering Properties of Venus at 3.8 cm	R.P. Ingalls J.V. Evans	Astron. J. 74, 258 (1969)

* * * * *

UNPUBLISHED REPORTS

Journal Article

JA No.			
3358	Boltzmann Equation Study of Hot Electron Relaxation in Metals	R.W. Davies	Accepted by Phys. Rev.

Meeting Speeches†

MS No.			
2424A	Diagnosis of Single Gate Failures in Combinational Circuits	R.N. Spann‡	Solid State Circuits Conference, Philadelphia, Pennsylvania, 19-21 February 1969
2460	Keeper Design for High-Density Magnetic Film Memories	T.S. Crowther R. Berger M. Naiman	Intermag Conference, Amsterdam, The Netherlands, 15-18 April 1969

* Reprints available.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

‡ Author not at Lincoln Laboratory.

Division 2

MS No.			
2497	Review of Proposals for Photon and Electron Beam Accessed Magnetic-Film Memory Systems	D. O. Smith	Intermag Conference, Amsterdam, The Netherlands, 15-18 April 1969
2507	Computer Assisted Integrated Circuit Photomask Layout	F. K. Richardson D. R. Oestreicher	Computer-Aided LSI Design Symposium, M. I. T., 10 April 1969
2520	Semiconductor LSI Design, Fabrication, and Evaluation	D. 1. Eckl	
2521	LSI Microprocessor Design	G. D. Hornbuckle	
2522	Circuit Simulation	H. B. Lee	
2523	Priorities and Objectives in the Design of Large Scale Integrated Computers	J. I. Raffel	
2524	Mask Making	F. K. Richardson	
2525	Logic Design and Test Generation	R. N. Spann*	
2526	TX-2 Hardware and Software Support	W. R. Sutherland	
2507B	Computer Assisted Integrated Circuit Photomask Layout	F. K. Richardson	Seminar on Computer Graphics, Cornell University, 15 May 1969
2517	Very Long Baseline Interferometry as a Means of Worldwide Time Synchronization	A. E. E. Rogers J. M. Moran	CCIR Study Group, U. S. Naval Observatory, Washington, D. C., 28 February 1969
2531	Vertical Wave Motions in the Ionospheric F Layer	L. A. Carpenter J. V. Evans	URSI Spring Meeting, Washington, D. C., 21-25 April 1969
2553	Radar Photographs of the Moon in 3.8 cm Wavelength Radiation	S. H. Zisk	Scientific Applications of Radio and Radar Tracking in the Space Program, Jet Propulsion Laboratory, Pasadena, California, 9-11 April 1969

* Author not at Lincoln Laboratory.

DIGITAL COMPUTERS
GROUP 23

I. CIRCUIT AND NEW MACHINE DEVELOPMENT

A. Semiconductor Processing

The 5- and 10-mW integrated gate ehains were reeeived from Phileo and evaluated. The average propagation delay per stage of the 5-mW ECL gate was measured to be 0.61 nsee and that of the 10-mW gate to be 0.53 nsee. Analysis of the dominant time eonstants of the gates indieates that the larger parasitie eomponents in the 10-mW gate limit the performanee improvement gained by inereasing the power level. A sample wafer of the 256-bit read-only memory array has also been reeeived for evaluation.

Other wafers are being proeessed with different values of resistor sheet resistivity so that measurements can be made at different power levels. A large emitter test strueture on the ehip has proved very useful in determining deviee yield, and will be ineorporated in future designs.

A flip-ehip substrate has been designed for the thermal evaluation ehip. Deviees with the neeessary bonding "bumps" are being fabrieated. These will allow power dissipation studies of flip-ehip mounted eireuits. A beam-lead version is in the design stage.

A set of masks for a multilevel proeess evaluation ehip has been fabrieated and sent to Philco-Ford Mieroeleetronies Division. This ehip will provide data on oxide pinholes, via eontinuity, and metal eontinuity over various struetures.

B. Gate Array

Masks are being drawn for an array of 80 three-input 5-mW ECL gates. This array will use gates and bias generators similar to those used in the gate-ehain integrated eireuit. Wide metal areas on first level will be used for power distribution. Logie signal intereonneetion will be done on seeond and third levels of metal. Metal intereonneetion patterns will be designed to form yield test ehains, eireuit-loading test ehains, adders, registers, and funetional multipliers from these gate arrays.

Numerous improvements were made to the mask-drawing program to expedite manipulation of the large data struetures required for the gate array. Masks have been ereated for the various diffusion operations and will be available soon for the metallization.

C. Chip Interconnection

Procedures have been developed for the assembly of arrays of integrated eireuit ehips east flush with the surface in filled plastie and also for the seleetive formation of plastic insulating layers over the ehips. Eleetroless metallization through vias in the plastie to the ehip metallization provides for eontaet between ehips and ehemieally deposited and photoetehed layers of intereonneeting wiring above.

D. Device Evaluation

An Eleetroglas Model 900A wafer probe has been installed and eonneeted to the TlC terminal. Experiments with the eontrol of the probe hcad with eomplex test patterns, using TX-2, are being eondueted.

E. LX-1 Microprocessor

Reeent work on the integrated eireuit version of the LX-1 mieroproeessor has concentrated in two areas: documentation, and a thorough review of the maehine design. As a result of thc review and further developmental work in the programming and applieations areas, ehanges have been made to the maehine as indieated below.

(1) A 64-bit buffer register has been added on the output of thc Control Memory (formerly called the read-only memory – ROM). This allows maehine exeeute eyeles to overlap eontrol memory read eyeles and frees a maehine register whieh was prcviously used for storage of the next eontrol memory address. Overlapped read/exeeute eyeles will allow the speed of the maehine to be almost doubled. It is expeeted that the basie machine eycle will be in the region of 80 nsec. The basic maehine eyele will be extended automatically to 1.5 or 2 times the normal duration whenever a lengthy execute eyele is required (add operation) and/or the next eontrol memory address is determined by the results of the present exeeute eycle.

(2) The Serateh Memory size has been doubled to 128 words. Machine eyeles relating to the seratch memory will be read-only or write-only.

(3) The "bootstrap" system needed to load a mieroprogram into the eontrol memory no longer uses the mieroproeessor. The external memory conneetion for loading the eontrol memory will be to another eomputer.

(4) A number of small features have been added to make the maehine easier to debug and maintain.

Work to be done in the immediate future includes backpanel layout, design and layout of remaining logic circuits for decoding and selection nets, detailed dcsign of the LX-1 control and design of the computer interfaee.

F. Semiconductor Memories

The TX-2 new PAM (Page Address Memory), 1024 words by 16 bits, has been completed and is now being tested. Its read time, ineluding the neeessary SPAT to MECL and MECL to SPAT level shifters, is 50 nsec. Its write time is also 50 nsee. The memory uses approximately 2200 MECL II integrated eircuits whieh plug-in on ninety 4 × 4 ineh four-layer printed circuit eards. The memory is packaged in a drawer 7 inehes high by 19 inehes wide by 20 inches deep. Power requirements are 100 A at – 5.2 volts.

The Microproeessor Control Memory, presently under eonstruetion, is essentially identical to PAM; the main differenee is that it is organized in 256 words of 64 bits eaeh.

II. MAGNETIC FILM ENGINEERING

A. Large Capacity Memory

1. LCM Digit Lines

The elimination of eapaeitive imbalanee noise in an LCM 1 staek by the use of a rigid digit line (0.040-ineh glass) has been demonstrated.

2. Digit Line Scribing

The large scribing machine is being assembled and should be operational within eight weeks. A deposition fixture to hold long glass digit substrates in the vacuum chamber is under construction. Experiments with laminating digit lines in carbonyl iron keeper on metal substrates show promise mechanically and thorough electrical evaluation is proceeding.

3. Word Line Scribing

Successful scribing with 0.1-mil wide tools has been achieved and is practicable. It has been established that magnetic layers exceeding 1800 Å thickness cannot be scribed since the high tool loading that is necessary occasionally forces the stylus through the magnetic layer and into the glass substrate, thereby causing tool damage. A precision substrate indexing unit is being installed which will eliminate existing line-to-pad alignment problems.

4. Word Line Flux Closure

Test samples of NiCo word line films on 1-mil centers closed around the copper conductor by electroless Co showed approximately the expected increase in output and decrease in writing current compared to unclosed films. A very thin (few thousand angstroms) electroplated copper film is required to smooth the conductor before low coercivity magnetic films can be plated.

5. Magnetic Film Plating

The coercivity of electrolessly deposited magnetic films decreases much faster with increasing thickness than that of evaporated films. It has been shown that the laminating of layers of magnetic film with similar thicknesses of nonmagnetic electroless Ni or Au permits making thicker films with the same high coercivity and low dispersion as the constituent magnetic layers.

B. Optical Testing of Magnetic Films

The minimum area of magnetic film from which a useful B-H loop (ratio of peak signal to RMS noise greater than 3) can be obtained with the miniature optical looper has been reduced to a 0.030-inch square. The looper bandwidth is 10 kHz. The limiting factor in these measurements is shot noise generated in the photodetector by radiation which arrives directly from the GaAs diode source without being reflected from the film being sensed. Therefore, significant reduction of the minimum area that can be looped is expected from improvements in positioning of the source and detector.

III. COMPUTER SYSTEMS

A. Display

A color display, using a two-layer penetration type CRT, has been designed and added to the TX-2 display system. This CRT has a limited range of color; however, the resolution is much better than the conventional shadow-mask TV color tubes.

B. Remote Terminals

A Computer Displays, Inc. ARDS Remote Display Terminal has been added to the TX-2 computer. Data are transferred between the ARDS and the TX-2 Sequence 57 teletype data

terminal at 1200 bauds/sec over hard wire. This terminal has an ASCII code keyboard and a Tektronix 611 storage scope with a vector generator and ASCII character generator. Software routines were developed which allow the terminal to act simultaneously as a console keyboard printer and display scope in the APEX environment.

COMPUTER COMPONENTS
GROUP 24

I. PERMALLOY FILMS

A. Determination of Ripple Spectra from Lorentz Micrographs

Fourier analyses of Lorentz micrographs of magnetization ripple have been carried out by (1) computer calculation from microdensitometer traces, using the fast Fourier transform,[1] and (2) optical diffractometer, using a stabilized argon laser. With both methods, conversion of electron intensity to magnetization direction has been done both classically and wave-optically.

Comparison of the wave-optical results obtained by methods (1) and (2) with one-dimensional ripple theory[2] indicates reasonable agreement for wave numbers $\lesssim 2 \times 10^5\ \mathrm{cm}^{-1}$. Shorter wavelength components are buried in crystallite noise. From the Fourier components, Parseval's theorem gives the mean ripple angle, allowing evaluation of the local anisotropy forces responsible for ripple. Preliminary results indicate local anisotropy energies of the order of $10^4\ \mathrm{erg/cm}^3$, which is consistent with magnetocrystalline anisotropy.

The optical transform method, in addition, gives the full ripple spectrum in two dimensions. The resultant propeller-shaped spectra are in rough agreement with two-dimensional ripple theory.[2]

B. Anisotropy Spectrum of Magnetic Films

Investigations continue into anisotropic resistivity processes, associated with the strain-magnetostriction anisotropy mechanism, in 90% Ni-10% Fe, 83% Ni-17% Fe, and 70% Ni-30% Fe films. Improvements in the AC bridge circuit have resulted in a half-order of magnitude improvement in the sensitivity of this measurement and an order of magnitude reduction of an unwanted mechanical relaxation process.

II. PEBA MEMORY SYSTEM

A. Heterodyne Detection

It has been shown[3] that the use of coherent mixing of the magneto-optic signal with a local oscillator (optical heterodyning) does not improve the intrinsic signal-to-noise ratio for a single selected bit. However, when background light is taken into account, heterodyning substantially improves the signal-to-noise ratio. The number of illuminated bits that can be read by one detector is then given by[4]

$$\eta \simeq \frac{1}{\sigma} \sqrt{\frac{N}{1 + \kappa/k^2}} \qquad (1)$$

where k = magneto-optical Kerr coefficient, N = total number of incident photons per read time, and κ = fraction of incident photons scattered into the nonmagneto-optical nonspecular background (NSB).

To provide a local oscillator signal having spatial phase coherence with the magneto-optical signal at the selected bit, the electron beam must create an optical inhomogeneity of sufficient

magnitude to cause substantial diffraction of the incident light. A particular physical realization of this principle has been suggested[3] in which the thermal dependence of the index of refraction of VO_2 is used to create the required inhomogeneity. Other physical effects such as the temperature dependence of the optical absorption of a suitably doped semiconductor can also be considered.

B. Proposal for 10^{-9}-Bit Random Access Memory

The general outline of a 10^9-bit random access memory using heterodyne detection has been given.[4] Recent measurements at this Laboratory of the absorption coefficient α and Faraday rotation F in EuO (Curie point $\simeq$77°K) have shown that between ~2 to 5 μ this material is transparent ($\alpha < 0.5\,cm^{-1}$) while $F \sim 5 \times 10^4$ to 5×10^5 deg/cm.[5] No other material is known which has such extremely large rotations and which is also transparent, both highly desirable properties for memory application. For $F \sim 10^5$ deg/cm, a value of $k \sim 10^{-2}$ can be obtained for films only a few thousand angstroms thick. Assuming 1 watt of optical power, $N = 10^{13}$ photons/μsec, and assuming $\kappa = 10^{-3}$ and $\sigma = 10$, Eq. (1) gives $\eta \sim 10^5$ bits/detector. In order to obtain 10^9 bits it is necessary to provide 10^4 detectors, which can be arranged in a square array, for example, with each detector having dimensions 1 × 1 mm. Optical access to the areas of magnetic film associated with each detector is provided by 100 optical reflections in one direction and a 100-position light deflector in the orthogonal direction. Finally, in order to provide for some reasonable degree of parallel access, 10 electron beams can be used along each optical reflection channel. Each beam is used to access a square of memory associated with one detector, i.e., a digit square, and all beams are deflected as a unit by means of a fly's eye electron lens.

C. Theory of Cooperative Emission of Radiation

Recently, Ernst and Stehle[6] have extended the Weisskopf-Wigner theory of radiation to the problem of the collective radiation from a system of N two-level atoms, which are assumed, at some initial time, to all be in the excited state, with no photons present in the radiation field. No preferential single cavity mode is assumed, and the emission is into free space (normalization volume of the photon field tends to infinity). In the Weisskopf-Wigner approximation, these authors are led to a system of 2^N integro-differential equations for the various expansion coefficients for the wave function of the system. Through various Ansätze and approximations built up through a study of the one- and two-atom problems, Ernst and Stehle arrive at a simplified system of (N + 1) equations for a set of coefficients in which the atomic states enter in a symmetrized fashion. The solution of these equations leads to the prediction of a strong, coherent, and very fast emission, provided the interatomic spacing is comparable to the optical wavelength. If such a phenomenon could be actually demonstrated, it would provide a very powerful method of optical readout.

We have found a much more transparent derivation of the same set of equations, and one which makes a connection with Dicke's[7] semiclassical theory of cooperative emission. For a system of N two-level atoms, it is well known that one can represent each atomic state by a two-component spinor in a pseudo-spin space. Dicke has shown that it is possible to construct eigenstates of the pseudo-spin operator

$$S(k)^2 = S_+(k)\, S_-(k) + S_z^2 - S_z \quad ,$$

$$S_\pm(k) = \sum_{i=1}^{N} S_\pm^i\, e^{\pm i\vec{k}\cdot\vec{R}} \quad ,$$

$$S_z = \sum_{i=1}^{N} S_z^i \quad ,$$

and it is these states which can give rise to strong coherent emission for mode k. We find that the treatment of Ernst and Stehle is completely equivalent to taking a reduced set of Weisskopf-Wigner states which can be generated from the initial state $|0;\uparrow\uparrow\ldots\uparrow\rangle$ of the system as follows:

$$|k_1 k_2 \ldots k_m\rangle = (\text{norm. constant})\, a_{k_1}^+ S_-(k_1)\, a_{k_2}^+ S_-(k_2) \ldots a_{k_M}^+ S_-(k_M)\, |0;\uparrow\uparrow\ldots\uparrow\rangle \quad ,$$

$M = 0, 1, 2, \ldots N$. These states are seen to correlate the creation of a photon in mode k, with the de-excitation of a coherent atomic state for mode k. In a sense, this can be regarded as an extension of the physical assumption on which the Weisskopf-Wigner approximation itself is based.

III. ELECTRON-BEAM SEMICONDUCTOR MEMORY

It is well known that if an electron beam impinges upon a depletion region fabricated near the surface of a semiconductor, electron-hole pairs are generated. The electrons and holes move in opposite directions in the field of the depletion layer, thus producing a measurable current which can be several orders of magnitude larger than the original electron-beam current.[8] It has also been demonstrated that an electron beam bombarding a metal-oxide-semiconductor (MOS) sandwich induces charge in the oxide layer; this stored charge influences the thickness of the semiconductor depletion layer,[9] and hence should influence in turn the electron-hole collection efficiency of the device. It is proposed to utilize these phenomena in an electron-beam memory in which the storage medium consists of a simple, homogeneous MOS sandwich. Those small areas (bits $\sim 1\,\mu$ in diameter) in the MOS which have been subjected to bombardment by a high-current writing electron beam will represent, say "ones," while other areas represent "zeros." A low-current reading beam is then used to interrogate the memory; the electron-hole reading current will differ for zeros and ones. It has been reported that the stored charge in an MOS device can be erased upon application of the proper bias upon exposure to the writing beam,[10] so that a read-write memory should be feasible.

Preliminary experiments have demonstrated electron-hole current collection upon exposing a metal-semiconductor device (no oxide layer) to a reading electron beam. Furthermore, pre-exposure of an area of the device to a writing electron beam causes a decrease in the electron-hole reading current. The latter effect is thought to be based on the charge storage mechanism discussed above, where the storage takes place in a thin contamination layer between the metal film and the semiconductor. The additional observation that the stored information vanishes upon exposure to the atmosphere remains largely unexplained.

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PSYCHOLOGY
GROUP 25

I. PROVISIONS FOR MAN-MACHINE INTERACTION ON IBM 360/67

A. Mediator

The redesigned Mediator, on which a subcontractor was finishing work at the time of the last report, has gone through acceptance tests and has been put into operation. The design is apparently quite clean: the number of bugs was relatively small, and they were corrected with commendable promptness.

The Mediator is essentially an on-line operating system. It makes use of the disk management and the terminal input-output facilities of CMS (the Cambridge Monitor System) and formally it has the status of a "command" within CMS. It augments CMS by providing three services that are important to a coherent library of programs: (1) automatic management of virtual memory, including automatic transfer of files and data to and from the disk when space is needed, (2) a pushdown list of programs that have suspended themselves and told the Mediator to execute other programs, and (3) a directory service that has cognizance both of files on the disk and of files that have never left the main memory. Putting the Mediator into operation has shown that the design was adequate; the Mediator appears to perform those functions with reasonable dispatch.

At present, the Mediator and the library of programs described below are in a "master" account in the 360/67 time-sharing system, and are available to seven "slave" accounts that have been used mainly in preparing the Reckoner library. During the next quarter, more operational experience will be gained, documentation will be completed, and the Reckoner and Mediator will be put onto the public disk where they will be available to all users of the time-sharing system.

B. Reckoner

As expected, once the Mediator was ready, the initial version of the Reckoner was constructed quickly. The programs were written largely in Fortran. They use Mediator services in place of the usual Fortran input-output, requesting those services via special assembly-language subroutines called "studs." Other studs provide linguistic and error-fielding services. About fifty programs have been written – mostly during this quarter. Half of them perform system and utility functions, e.g., keyboard input, typewriter output, building processes, editing of character files, etc. The other half are numerical operators mainly concerned with element-by-element array calculations and matrix algebra. Taken together, these programs constitute a Reckoner, an environment in which the nonprogrammer can inspect and run calculations on quantities of data. Furthermore, any experienced Fortran programmer using the "studs" should have little difficulty in writing new programs for this environment. In fact, a good part of the library was prepared by relatively inexperienced programmers.

II. PROVISIONS FOR MAN-MACHINE INTERACTION ON TX-2

Hardware and software are now available to allow the APEX time-sharing system to be operated from an Advanced Remote Display Station (ARDS-11). ARDS is a console made up of a

keyboard and a storage display driven from local character and vector generators. The console provides both character stream input-output, as in the more usual keyboard-typewriter console, and also graphic input and output. When the display capability is used, the executive input-output routines divide the screen, allowing 18 lines of typing at the top and a square picture area at the bottom of the rectangular storage scope face. If displays are not required, a 58-line page of characters can be used. Present operation is equivalent to the use of the console on a 1200-baud full-duplex telephone line. The use of full duplex allows input keying to proceed while output is being transmitted as well as to allow an arbitrary choice of the character(s) which appear on the screen in response to a key being struck. The latter feature is particularly desirable in the TX-2 environment, since the ARDS character set differs from the standard TX-2 character set. With the addition of the ARDS console, the APEX system now has the capacity to communicate simultaneously with a total of ten terminals. All ten are rarely in use at the same time, but eight busy consoles is not an uncommon load.

III. HUMAN FACTORS IN ON-LINE COMPUTATION

Experimentation on the effect of response delays on on-line problem solving continues. The experiment mentioned in the last quarterly report – an experiment in which the delay in the machine's response varied at random around a mean value of 1, 4, 16, or 64 seconds – was resumed and has been completed. The data are being analyzed.

IV. HUMAN INFORMATION PROCESSING

Experiments now in progress have shown that the latency of response to an initial low-intensity flash can be decreased by the subsequent occurrence of a flash whose intensity is either equal to or greater than that of the initial flash. When the second flash is much more intense, the speed of response to the pair of flashes is the same as the speed that is observed when the second flash is presented alone, as if the first flash had no influence at all. Thus the experiments have captured, within a single context, the essentials of studies of temporal stimulus integration, on the one hand, and retroactive inhibition or backward masking, on the other. Because these two aspects of temporal visual processing have usually been examined in different contexts, it has been difficult to interrelate the separate findings within one theory. The present determinations may help to bridge the conceptual gap.

COMPUTER SYSTEMS
GROUP 28

I. COMPUTER CENTER DEVELOPMENT

Work on the CP/CMS time-sharing system has consisted of the implementation of a number of useful features as well as a look into the future. A series of discussions is being held to consider long range goals for the facility. Since the people involved include both users and systems programmers, there is a beneficial exchange of ideas. An immediate outgrowth of these meetings has been the formation of a small committee to begin work on an improved batch capability. The present CP/CMS batch operation is capable of little more than assemblies, compilations, and short execution jobs with very limited input and output. Users of the time-sharing system who require longer execution jobs or more input and output facilities are faced either with impractically long vigils at their terminals or the considerable inconvenience of making the appropriate changes to run the work under the OS/360 batch monitor system. The committee is at work to provide facilities under CP/CMS that will be functionally equivalent to those offered by OS/360, with the added features of compatibility and ease of use, including job entry from user terminals.

Among the operational and system features added to CP/CMS were some to provide the user with improved capabilities and some to permit easier access. Two operational changes which seem to have provided some relief for overcrowded lines were the extension of hours to 10:30 PM daily and from 9:00 AM to 5:00 PM on Saturday, and the allocation of two reserved lines. Users who are unable to obtain access by the conventional techniques may call the Computer Dispatcher to reserve up to one hour of terminal time. At the scheduled session, the user calls the Operator from his own terminal and is connected to the system on one of two lines which are not accessible by the normal user. The advantage of this method over scheduling a single terminal directly connected to the computer lies in the fact that the user may work at any terminal in any location he chooses. On the basis of brief experience, it seems that the availability of a scheduled access to the system has permitted users to feel somewhat freer about logging out as soon as they have completed a useful session. Without this possibility of access, a user is virtually obliged to hold a line, even if he is not active on it.

A problem closely related to this has been substantially improved by the implementation of a line-holding feature. Once a user logs out of the system, his line becomes available to anyone and everyone who might be trying to access the system at that moment. There was no way to pass a line on to a different user at a given terminal unless he was going to continue using the same account, files, and identification. The "hold" feature permits a user to log out and hold the line for a five-minute period during which another user may log into the system from the same terminal. This, of course, permits informal scheduling of a terminal in a local work area.

Two of the many other new features which are of particular note are "shared files" and "warm start." The former refers to the fact that a user may now share files with up to five other accounts on a read-only basis. While this is not the full extent to which file sharing will be implemented, it is a useful first step that provides access in common to both data and programs.

The "warm start" feature refers to the fact that output data awaiting processing at the time of a system failure are lost because the system is restarted by loading in a fresh copy from disk. This new copy, knowing nothing of what has gone before, is unable to print or punch the data which were awaiting processing. The only recovery would be for all users concerned to rerun their work. The "warm start" procedure preserves certain pointers such that the fresh copy of the system can continue to process output data from the point at which the system failed.

IBM's Release 16 of the OS/360 batch monitor has been installed at the Laboratory. Among the improvements provided are a new version of Fortran (H-level), extensive error control facilities under Fortran, a more efficient linkage editor, and compatibility with the newly improved accuracy of the floating point hardware.

II. LISTAR (Lincoln Information Storage and Associative Retrieval System)

Over the last quarter, programs for making references across block boundaries were fully checked out and tested. Other programs that permit a user to add entries to a file from tape or disk or terminal were checked out and tested. Programs are in preparation which permit a user to define a file by way of a terminal command, delete entries from existing files, and create a simple relation between entries in one file and entries in another file.

SURVEILLANCE TECHNIQUES
GROUP 31

I. SUMMARY

Group 31 conducts the research program of Lincoln Laboratory's Millstone and Haystack radar/radio research facilities.

In addition to the radar propagation work reported to the Advanced Ballistic Missile Defense Agency (ABMDA), the L-band Millstone system continues to support Thomson scatter studies of the E-region and to support the optical sensor development program with satellite data. Thomson scatter measurements at UHF have also continued with graduate student participation. One very interesting set of data was obtained during an active aurora.

In addition to continuing radar observations of the moon, Mercury and Venus, partly with NASA sponsorship, a highly successful Haystack-Westford radar interferometer Venus experiment was conducted. Water vapor studies have continued to be the radio observing program of most interest this quarter.

II. SPACE SURVEILLANCE TECHNIQUES

Much of the work of this program is now reported in quarterly letters and semiannual reports to ABMDA. Remaining work includes radar auroral investigations and orbital tracking which is of assistance in the optical and IR sensor research being conducted by Division 5 at the Firepond Research Facility near Millstone.

During the weeks of 31 March and 28 April 1969, auroral data were taken while alternately transmitting 500- and 50-μsec pulses to obtain good resolution in both Doppler and range. Auroral echoes were obtained on nine of the ten days, and a large quantity of data was recorded using a short (2-pulse) integration with the antenna at fixed positions and a long (25-pulse) integration while scanning the antenna in azimuth at different elevation angles. These data will permit study of both the microstructure and macrostructure of the echo medium. A computer program that will summarize the data for evaluation and analysis planning has been completed.

Satellite tracking activities in support of the Firepond program depend upon favorable weather, and have averaged about one-half day per week during this quarter. Near the end of the quarter, several nighttime passes of Echo II were observed in order to update its orbit more frequently as the object approaches decay.

III. HAYSTACK PLANETARY RADAR

A. System Development

Most of February and early March, while the radar was off the antenna, were devoted to obtaining a satisfactorily operating pair of VA-949AM transmitter klystrons from the available units. Several troublesome units were returned to the manufacturer for evaluation and possible rework. Two tubes were finally selected which consistently permitted transmitter operations at a 320-kW level during the extensive lunar and planetary observations carried out between

10 March and 18 April. Delayed maintenance and system improvements were emphasized for the remainder of the quarter.

Satisfactory radar operations were obtained with the dual-channel maser receivers with typical system temperatures of 43°K in the left circular channel and 85°K in the right (reflecting the extra losses due to circulators and other elements in the transmitter microwave system). Unfortunately, gain variations with elevation angle and liquid helium level limited performance of these receivers as continuum radiometers. A sky horn as a switched radiometer reference was installed to alleviate the effect of this problem.

The Haystack-Westford (Hayford) radar interferometer system was reestablished with substantially greater sensitivity than it provided for the 1967 Venus mapping experiment. The Haystack single-channel maser was installed on the Westford antenna in place of the paramplifier used previously, yielding part of this gain in performance. The remaining factors were (a) Haystack antenna improvements due to the "rerigging" and (b) improved Haystack transmitter performance. The help of Group 62 was indispensable in instrumenting Westford.

Improvements were made in the direct data interface between the receiver system and the CDC 3300 computer in order to assist certain specialized experiments. A modification was also made in preparation for the incorporation of a real-time decoder into the radar system. This element will take over from the CDC 3300 processing software the task of decoding the pseudo-random phase modulation of the planetary radar signal in ranging experiments, thus freeing computer time for other tasks.

B. Planetary Studies

1. Hayford

The results of 7840-MHz observations of Venus made near the 8 April inferior conjunction with the Hayford radar interferometer are most encouraging. The overall signal-to-noise ratio is about 10 dB better than that obtained in 1967, mainly because of the aforementioned system improvements and partly because of more favorable observing conditions.

The radar maps obtained cover a region from about −80° to 0° longitude (Carpenter's definition) and about −50° to +40° in latitude. Processing of the interferometric data successfully freed the resulting maps from the twofold ambiguity inherent in monostatic range-Doppler mapping.

The maps reveal many new features and clearly delineate features already observed. Most notably, the maps show large circular regions of significantly lower reflectivity than their surroundings.

2. Monostatic Observations

In addition to the Hayford measurements, routine Venus ranging observations were also made for the fourth test of relativity, and CW spectral measurements of Venus were made in both polarizations. These data show the movement of certain features and further define the planetary scattering laws. Results will also be applied to the derivation of radar cross section over a complete rotation of the planet.

Also attempted, despite severe stress on the schedule, were observations of Mercury near its superior conjunction, which also occurred upon 8 April. Optimum performance is required for valid data at such ranges. Unfortunately, a day of equipment problems alternated with a day

of bad weather to compromise the measurements near conjunction – more regrettably because routine Mercury range measurements went well at other times during the quarter.

C. Lunar Studies

Of the 227 ZAC subareas into which we have divided the near surface of the moon, 187 (85 percent) have been successfully measured with apparently good data. An additional 19 areas (out of 36) have been measured in ZAC ring 10.0 on the "far" hemisphere (zenith angle 90° to 100° from the zero-latitude/longitude point).

To date, 40 of these measurements have been processed into pairs of photographic maps in the polarized and depolarized radar return. These maps show excellent resolution and clarity over ZAC rings 1.0 to 8.0, and a somewhat increased noise level at ZAC ring 9.0. The signals returned from ZAC 10.0 are so weak, however, that only a few features are visible through a screen of noise "snow." Work on the tenth ring will probably not be completed except for those areas that are of particular scientific interest.

On 24 and 25 March, we operated for two periods of 15 consecutive hours each, during which time we took calibration measurements on the leading edge of the moon (center of the visible dish) at 2-hour intervals. The results of these measurements were corrected for instrumental effects and then compared with the Eckert (JPL-integrated) lunar ephemeris for both Doppler and range. As was true during last year's lunar mapping program, unexplained discrepancies were found in Doppler but not (to our 2-μsec resolution) in range. The Doppler discrepancies, being a much more sensitive measure of the moon's position, are consistent with an unmeasurable 2-μsec or less range error. No explanation has yet been found.

IV. THOMSON SCATTER

Synoptic observations of ionospheric temperature and density have been made once per month for a 24-hour period and a second 24-hour period has been employed for determining vertical drifts. Special observations were made on the night of 21/22 March during an active aurora which yielded results of extreme interest. During the period the aurora was in progress, the F-region electron temperature was typically observed to be between 3000° and 4000°K. This is more than twice the normal value for the nighttime in March and correlates well with the 6300 Å airglow intensities observed by Professor Noxon at Harvard. Twelve-hour observing periods with the L-band radar have also continued at a rate of two per month, except during March when other station activities prevented them.

Observations of the plasma line of Thomson scattering terminated on 6 April after an interesting set of data had been collected on the nocturnal intensity of the line. This work was undertaken largely by a graduate student at the University of Michigan, Irvin Gastman, who has now returned to complete the analysis of his data. The line is detectable at night (in winter) because photoelectrons are produced at the magnetically conjugate point (which remains sunlit) and travel along the earth's field lines into the local ionosphere. Thus, by studying the arriving flux in this way, together with the escaping flux (in the daytime), one may hope to learn something of the properties of the protonosphere through which the photoelectrons must pass.

A storm on 24 February piled snow up to 2'6" in depth in the center of the 220-foot zenith antenna. This was removed by hand, but the gain was then found to be only 58 percent of its

prestorm value, presumably because of the pulling and stretching the mesh had undergone. A survey of the antenna was ordered and has recently been completed, though the results are not yet available. In the interim, the gain has increased somewhat and is now 75 percent of its prestorm value. This upward adjustment probably arises from the mesh "creeping" toward its original contour as a consequence of daily thermal expansion and contraction. However, we intend to try to restore the dish to normal performance this summer.

V. RADIOMETRIC TECHNIQUES

A. Instrumentation

The Haystack Radiometer Box (R-box) was on the antenna 7 February – 10 March and again 18 April – 5 May in support of observations at 1666 MHz, 7.5 to 8.5 GHz, 15 to 16 and 22 to 24 GHz. During other times, improvements were made as described below.

1. K-Band Systems

A new Lincoln-built K-band (22 to 24 GHz) feed was installed in the R-box, replacing one provided by M.I.T. The new feed provides simultaneous reception in either right and left circular or horizontal and vertical polarization. Ability to switch quickly between orthogonal polarizations enhances the accuracy of polarization measurements.

While the Planetary Radar Box (PR-box) was on the test dock in April, preparations were made to mount in it the K-band radiometer from the R-box. This will provide the ability to carry out K-band, particularly H_2O vapor, radiometry when the PR-box is on the antenna, during times the radar is not actually in use.

Improvements to the K-band local oscillator system increased its stability and provided for changing its frequency by 8 MHz in less than 10 msec. Frequency switching so provided was used extensively in the April water vapor observations.

2. X-Band Systems

The old liquid-nitrogen-cooled X-band parametric amplifier, used for spectral line and very long baseline interferometry (VLBI) work since last fall, was replaced by one of Lincoln's new computer-designed room-temperature paramplifiers. System temperatures near 160°K were achieved. Whilst this is several times the temperature of the maser receiver in the PR-box, its wider tuning range (500 MHz) guarantees its use for many spectral line and VLBI experiments. With the addition of an IF amplifier able to pass the full 100-MHz bandwidth of the new paramplifier, this radiometer will compete well with both the tunnel diode radiometer and the PR-box maser receiver for X-band continuum work.

3. Lobe-Comparison Radiometer

To provide an improved means of evaluating the pointing errors, repeatability, backlash and general pedestal and pointing data pickoff performance of the Millstone 84-foot tracking antenna, a wide-band lobe-comparison radiometric system was implemented. It effectively compares, simultaneously, signal amplitudes from equally offset lobes in both elevation and traverse planes. On strong sources, off-boresight deviations of a few arc seconds are readily discernible. Where lobing feeds can be readily applied, this is a powerful technique for quickly evaluating general antenna pointing performance.

B. Radio Astronomy

Water vapor emission at 22.235 GHz was extensivcly observed at Haystack. It is interesting that in nine out of ten cases the sources of anomalous OH emission are also very intense sources of water vapor emission. Since the beam size at 22 GHz is 1.5 arc minutes and the RMS pointing accuracy is 12 arc seconds, we have been able to establish the coincidence of water vapor emission with the interferometer-determined OH-source positions and to set new upper limits ($\leqslant$ 30 arc seconds) on the angular size of the water vapor sources.

Our measurements of line shape and time variations (over intervals as short as a week) have made it seem reasonable to conclude that H_2O is emitting through maser action, as in the case of OH.

Haystack has proven unusually well suited to measuring spectral lines around 1-cm wavelength. Observations of the ammonia transitions, reported previously, have been continued.

We have also begun a series of observations of the sun's rising and setting in an attempt to detect absorption lines from H_2O in the stratosphere. Presently, microwave observations provide the most sensitive method for detecting stratosphere H_2O. Our initial measurements this spring have shown the mixing ratio above the tropopause to be less than a few parts per million.

A search for microwave emission from excited states of OH around 8 and 23 GHz were made, and the state $^2\Pi_{1/2}$, J = 5/2 was detected in the 18-cm OH source W3. Our search for time variations in OH emission has continued, and we remeasured the 1665-MHz Stokes parameters in W3. These measurements show small but significant changes since 1966.

The program of measurements to observe time variations in continuum radio sources (quasars and peculiar galaxies) is continuing. Initial measurements were made at 23 GHz during this quarter; these observations supplement the systematic observations at 8 and 15 GHz which extend back to 1965.

As part of the continuing program of observations of galactic HII regions, we have investigated the relationship between some 25 HII regions and their reported exciting stars. Comparison of the observed radio flux and the ultraviolet flux, theoretically predicted from recent calculations of model atmospheres, show that most HII regions cannot be supported by those exciting stars. Apparently, the true exciting stars are obscured, optically, by gas and dust surrounding the HII region.

Cooperatively with H. E. Radford of the National Bureau of Standards, we engaged in an attempt to measure frequencies of UHF transitions of the SH radical. This experiment, partly supported by Group 76, involves measuring the transmission of a resonant cavity (filled with SH gas) as a function of frequency. The first attempt was unsuccessful. The gas ionized at electric potentials used for frequency modulation of the lines by Stark effect. The next attempt will employ modulation by Zeeman effect.

RADAR
DIVISION 4

INTRODUCTION

The Radar Division conducts a General Research Program to develop new radar components and techniques which appear useful in future systems. The activities for the period 1 February through 30 April 1969 consist of continuing work in the development of new devices and techniques for solid state power generation and amplification, experimentation in precision timing components and further exploration of microwave acoustics (microsound) applications. Separate reports are issued on the RDT, PRESS, RSP and MTI radar programs.

H. G. Weiss
Head, Division 4

DIVISION 4 REPORTS ON GENERAL RESEARCH

15 February through 15 May 1969

PUBLISHED REPORTS

Technical Report

TR No.				DDC No.
457	The Microwave System of the Haystack Planetary Radar	C. W. Jones	23 October 1968	DDC 685696

Technical Note

TN No.				
1969-17	Pointing Accuracy of Lincoln Laboratory 28-Foot Millimeter-Wave Antenna	T. R. Gull J. J. G. McCue	14 February 1969	DDC*

* * * * *

UNPUBLISHED REPORTS

Journal Article

JA No.			
3431	Some Problems in the Theory of Guided Microsonic Waves	R. A. Waldron	Accepted by IEEE Trans. Microwave Theory Tech.

*Not yet assigned.

MICROWAVE COMPONENTS
GROUP 46

I. INTRODUCTION

Group 46 contributes to the radar program through direct participation in specific projects, and through a program of general research which is closely related to the microwave needs of the Laboratory. Continuing programs are in the areas of microwave acoustics (microsound) and diode-using devices. The millimeter wavelength lunar radar program has been terminated and a final report is imminent. The computer-aided design program, which produced the GCP (General Circuit Parameters) computer program, now being used throughout the Laboratory for the solution of microwave circuit problems, is no longer active. The solid state diode device work is being re-oriented and will include a study of new devices and techniques which are beginning to be important in solid state power generation and amplification.

II. DIODE-USING DEVICES

A. Low Noise Balanced Diode Mixers

The S-band balanced diode mixer designed for use at 3 GHz has been tested for overall noise figure and for the noise figure contribution of the mixer stage alone. The overall noise figure which included a 2.4-dB IF stage (60 MHz) was measured to be 6.5 dB. The circuit loss for the breadboard device has been measured and is approximately 2.0 dB. The theoretical noise figure of the S-band mixer has been calculated to be, for the diodes used, approximately 0.6 dB, not including any microwave circuit loss. Therefore, there is approximately 1.5 dB of loss or noise figure which has not been accounted for. This is undoubtedly due to a relatively poor matching network into the diodes at both the signal and the LO. The VSWR of approximately 3:1 would account for most of this. In addition, the LO power at each diode was not considered to be adequate. The matching structure for the diodes is being studied and an LO generator with greater power has been obtained.

It is intended that once the matching structure and LO power requirements have been examined that work on the low-noise mixer be terminated. The principle of operation has been verified experimentally.

B. Solid State Power Sources

Prior studies of IMPATT diodes have restricted their considerations to one-dimensional models of these devices. Some qualitatively new modes of behavior have been brought to light by a study of a more realistic multidimensional structure. These include new bulk-wave avalanche modes and a new type of avalanche phenomena most easily described as surface wave avalanche modes. It is hoped that the use of these modes will lead to improved high-power, high-efficiency avalanche devices.

III. TIMING TECHNOLOGY

The purpose of this program is to demonstrate the feasibility of a one-way radar or DME concept using present-day state-of-the-art technology. The use of nanosecond coded pulses and remotely synchronized clocks is fundamental.

Two cesium beam frequency standards have been obtained for the purpose of studying the problems of clock synchronization. After about one month of observation, it has been determined that the two clocks track one another to approximately $\pm 1 \times 10^{-13}$.

Work is proceeding to breadboard demonstration equipment and to set up an experiment for determining the nature of the multipath problem which is expected to be encountered.

IV. MICROSOUND PROGRAM

A. Transducer Fabrication

During the past interval, electron beam resists were fabricated and tested at the M.I.T. facility. It was found that polymethyl methacrylate could be used to achieve line widths of 3000 Å. A tapped surface acoustic line was built and tested. The results indicate that two-finger pairs are adequate for tapping purposes. The response of the device to an impulse was shown to be the derivative of the impulse.

B. Acoustic Amplifiers

A new acoustic amplifier structure was fabricated, assembled and tested in a pulsed mode. An acoustic gain of approximately 2 dB was realized. Further increases in the applied potential produced a noisy response. Investigation revealed a faulty ohmic contact in the silicon wafer as the source of difficulty.

C. Guided Elastic Waves

In connection with the microsound program, studies are being made of the theory of guided elastic waves, with a view to ultimately being able to design microsound circuits analogous to present-day microwave circuits. A waveguide that is likely to be used in practice consists of an overlay of rectangular cross section on a more rigid substrate. As a theoretical model of this, the substrate has been considered as perfectly rigid, and the complete mode spectrum of the model has been elicited. Phase characteristics have been calculated for the important modes, and some idea has been obtained of the forms of the displacement functions. Using methods developed for treating the above problem, the case of a waveguide with nonrigid substrate is currently being studied.

The first phase of an analysis of microsound (acoustic) waveguide has been completed and a paper has been submitted to the Journal on Microwave Theory and Techniques. The analysis treated the case of an ideal rectangular isotropic acoustic waveguide (rod) that has one surface clamped to an acoustically rigid substrate.

V. MILLIMETER WAVELENGTH PROGRAM

The millimeter wavelength lunar radar operated well in February and yielded a useful set of data on lunar reflectivity and depolarization at a wavelength of 8.6 mm. The transmitted polarization was circular. Both circular polarizations were received.

From center to limb, the reflectivity (on a power basis) drops by a little more than 5 dB for heavily cratered regions. The maria are less reflective than the regions that are bright to the eye. The crater Tycho, which gives exceptionally strong returns at longer wavelengths, reflects only 2 dB more strongly than Mare Humorum viewed at the same angle of incidence (with a beam whose two-way 3-dB width is 0.05 deg, covering the Mare Humorum and an area of equal size around Tycho).

The depolarized or orthogonal return, in circular polarization, expressed as a fraction of the return in the "expected" circular polarization, is 18 percent at the subradar point and 50 percent at an angle of incidence of 70 deg.

This last series of measurements completes the experimental phase of the millimeter wave lunar measurement program. A final report is in preparation.

OPTICS
DIVISION 5

INTRODUCTION

This section summarizes the General Research efforts of Division 5 for the period 1 February through 30 April 1969. A complete presentation of the Optics effort may be found in the quarterly Optics Research Report and in the Semiannual Technical Summary and Quarterly Letter Reports to the Advanced Research Projects Agency.

A. L. McWhorter
Head, Division 5

R. H. Kingston
Associate Head

DIVISION 5 REPORTS ON GENERAL RESEARCH

15 February through 15 May 1969

UNPUBLISHED REPORTS

Journal Article

JA No.			
3491	Perturbation of the Refractive Index of Absorbing Media by a Pulsed Laser Beam	P.R. Longaker M.M. Litvak	Accepted by J. Appl. Phys.

Meeting Specches*

MS No.			
2479	Diode Laser Linewidth Measurements	E.D. Hinkley C. Frecd	American Physical Society, Philadclphia, Pennsylvania, 24-27 March 1969
2534	Laser Beam Broadening in Atmospheric Propagation	T.J. Gilmartin	Optical Society of America, San Diego, California, 11 March 1969

Technical Report

TR No.			
464	Effect of Diffusion on Gain Saturation in CO_2 Lasers	H.A. Haus† C. Freed C.P. Christensen†	7 February 1969

* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

† Author not at Lincoln Laboratory.

OPTICS AND INFRARED
GROUP 53

The CO_2 laser radar program includes the experimental work associated with the high power CO_2 laser radar system, some aspects of the experimental work associated with the IR tracking radiometer and the supporting component research and development carried on concurrently with the systems work to provide components and information to both systems and other Laboratory programs. The supporting research is primarily concentrated on gas lasers, solid state detectors, tunable oscillators, and optical techniques and components.

The installation of the CO_2 laser radar has been completed and the system has been operated in the CW mode at reduced power. Returns from tower-mounted targets, including corner cubes and a convex specular sphere, have been observed. Coherent returns from a small aircraft have also been recorded.

The sensitivity of the IR tracking radiometer has been improved and automatic tracking and signal recording have been accomplished on the Echo II and Pageos satellites and the planetary targets, Venus, Jupiter and Mercury. Aircraft targets have also been tracked in the course of providing pointing data to the CO_2 laser radar.

Work on improving the polarization stability, tunability, and frequency stability of laser oscillators has continued.

Measurements of the short term stability of an improved laser oscillator have been made. An investigation of the spectral peak predicted to occur in the amplitude fluctuation noise of a CO_2 laser is under way.

Experimental observation of the output power spectrum of a $Pb_{0.88}Sn_{0.12}Te$ diode laser operating above the oscillation threshold has continued.

ENGINEERING
DIVISION 7

INTRODUCTION

The Engincering Division supports the General Research program of the Laboratory by designing and fabricating mechanical and scrvo-control devices for our installations at Haystack and Millstone Hill, as well as for solid state rcsearch. The Division's integratcd circuit facility is coneerned with developments in all phases of mieroelcetronics.

During the quarterly pcriod from 1 February to 30 April 1969, work at Haystack ineluded thc installation of a 23-GHz dual fced assembly in the radiometer box and the careful tcsting of the eomponents of a dual maser system to provide eryogenic temperatures for extended periods of time. For Millstone, a new frequcncy-selective subreflector and monopulse fced assembly are nearing eompletion, and these will be installed on the 84-foot tracker. At the adjacent Firepond Infrared Research Facility, installation of the three-mirror reflceting system has been completed, as well as its control system. Additional work is being done on thc television monitoring system and safety cnclosures to protect operating personnel.

The Integrated Circuit Facility, although operating in temporary quarters pending the eompletion of adequate faeilities, is making signifieant progress in its research and development programs. Chief among these are thc development of metalization systems for beam lead substrates, the fabrication of Impatt diodes and MOS capacitors, and custom metalization for a variety of applications. Automated layout of eireuits is being developed in a parallel effort.

J. F. Hutzenlaub
Head, Division 7

DIVISION 7 REPORTS ON GENERAL RESEARCH

15 February through 15 May 1969

PUBLISHED REPORTS

Journal Article

JA No.			
3379	Beam Lead Substrate Assembly Techniques and Applications	R. E. McMahon R. A. Cohen	Electronics 41, No. 25, 95 (1968)

* * *

UNPUBLISHED REPORTS

Meeting Speech*

MS No.			
2457	The Fabrication of Microsound Components	H. I. Smith	IEEE International Convention, New York, 24-27 March 1969

* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MECHANICAL ENGINEERING
GROUP 71

I. HAYSTACK

A. Radiometer Box

The 23-GHz dual feed assembly has been installed in the radiometer box and is being tested by Group 31. Circular polarizers ranging from 22.2 to 23.1 GHz are being made of a standard length to enable quick interchange. These will be positioned between the feed horn and the waveguide.

Studies are being made to install a 1000-lb-capacity electric hoist on the antenna above the raceway structure to facilitate handling problems encountered when mating the front feed section to the radiometer box and also when handling the Cox fan-coil chiller during box changes.

B. Cryogenics

The simulated dual maser structure was installed in the closed cycle refrigerator with instrumentation to monitor the structure's temperature. The refrigerator was cooled down to below 4.2 °K and maintained its temperature until shut down. The temperature of the maser structure followed that of the refrigerator during cool-down.

A superconducting magnet, similar to the one used in the Nos. 2 and 3 masers, is being fabricated at the Haystack Facility. This magnet together with the maser comb structure, less the ruby loading, will be cooled in the refrigerator to evaluate the thermal loading of this portion of the system prior to attempting to cool the entire working maser package.

II. MILLSTONE

Conferences are continuing with Philco Ford Corporation, Palo Alto, California, to define the mechanical interface of a new frequency-selective subreflector and UHF monopulse feed assembly which will replace the existing subreflector of the 84-foot-diameter Millstone tracker. Mechanical layout assemblies have been agreed upon and detailed manufacturing drawings are being made. Delivery is scheduled for July 1969.

Studies are also being made to mount a shaft-position encoder on each elevation and azimuth axis. In elevation, the encoder can be mounted and aligned on the torque tube axis; however, in azimuth, because of the waveguide and rotary joint configuration, an off-axis cam arrangement has to be used. In addition, studies are being made for an azimuth cable-wrap to supplement the existing slip-ring assembly during operations with the new frequency-selective subreflector.

III. SOLID STATE RESEARCH

A. Belt Apparatus (High Pressure Device)

Redesign of hardware to be used in the belt apparatus has been completed. Comparative pressure data, based on the polymorphic transition of barium and bismuth are:

	Old Apparatus (tons)	New Apparatus (tons)
Bi (25 kb)	50	50
Ba (60 kb)	170	150
Bi (83 kb)	310	245

It is further noticed that our success in retaining the integrity of measurement leads in the new system is far greater than with the old system.

B. Crystal Pullers

Because of the considerable interest in growing crystals under pressure, it has become important to develop some method of lowering or raising the melt from the heat zone.

One puller is designed to do just that. This system translates a linear and rotational motion to a crucible which is positioned in the pressure chamber with the rotations variable between 1 rpm and 1 rph, and the feed variable between 1 inch per day to 1 inch per hour. A second unit is a horizontal puller which can also be used for zone refining. By this method a small part of the rod-shaped material is melted as the heater is slowly moved from one end to the other, thereby moving the molten portion of the material. The feed, however, needs to be exactly reproducible at 1/4, 3/8 or 1/2 inch per day. This is accomplished by utilizing reducer boxes as interchangeable cartridges which can be coupled to the system.

IV. CO_2 LASER RADAR (Firepond Facility)

Installation of the 3-mirror mount system has been completed. Recent efforts have concentrated on the installation of the declination axis brake system on the tracking mirror mount.

The television monitoring system is being redesigned to allow continuous rotation of the camera instead of the present limited angular travel.

Safety enclosures to prevent personnel from walking through the laser beam paths are being constructed and installed. Acoustically damped enclosures for housing the two laser oscillators are being designed.

V. NEROC

A small group effort on the design and analysis of a large steerable antenna for NEROC (NorthEast Radio Observatory Committee) is being conducted. Formal reporting is done separately.

CONTROL SYSTEMS
GROUP 76

Checkout of the control system at the Firepond Infrared Research Facility was completed, and satisfactory performance in all operational modes was demonstrated. These modes include computer directed pointing for both mounts, slaving of the laser radar mount to the cold tracker mount and vice versa, slaving of both mounts to the Haystack or Millstone radar, and manually directed pointing for both mounts. The only items still to be completed are installation of the television camera line-of-sight rotation system and revision of interface circuitry to accept inputs from the proposed new shaft angle encoders of the cold tracker mount.

MICROELECTRONICS
GROUP 77

During the past quarter notable progress has been made in several research and development programs underway in the Integrated Circuit Facility.

A metalization system for beam lead substrates has been selected after an evaluation of several possible systems. The choice of molybdenum-gold, where both metals are sputtered in a single pump-down in an RF diode sputtering unit, provides excellent substrate adhesion and repeatable bonding results. Current work on the beam lead substrate concept centers around developing techniques for producing air-isolated crossovers particularly for ceramic substrates. Large beam lead substrates accommodating 36 optional windows for use with monolithic chips are under development and will be applicable to system fabrication very shortly. Microwave strip lines employing the beam lead structure are also under development.

Custom metalization of complex monolithic chips is continuing and improved handling techniques have greatly reduced the amount of chip damage during processing. The custom metalization procedure has shifted emphasis from silicon dioxide isolation to isolation with standard photo-resists and paralene N.

A program to develop Impatt diodes with special characteristics was initiated during the last quarter. The material and diffusion steps have been completed and the initial Impatt diodes have exhibited an avalanche voltage of 65 V at a 10-μA leakage. Large ohmic contact resistance has been reduced by the use of a nickel strike plating, and packaged Impatt diodes useful for frequency measurements should be available shortly.

Metal oxide semiconductor capacitors have been the goal of another development program for use in an electron beam memory application. Good surface states have been achieved, but some oxide pinhole problems remain with oxide thicknesses of 1000 Å or less.

Planar diodes and transistors are currently being fabricated for general use in hybrid integrated circuit fabrication and as a preliminary entry into monolithic circuit fabrication.

A master mask has been designed that contains four 50-mil-square quadrants having numerous diodes, resistors, capacitors, transistors and MOS and bipolar integrated circuits, for use as an evaluation tool and as a source of components for hybrid units.

The development effort on surface wave transducers has resulted in the fabrication of delay lines on lithium niobate, nonpiezoelectric delay lines using interdigital transducers over cadmium sulfide pads on sapphire, fused quartz and yttrium iron garnet (YIG). In addition, amplifiers have been fabricated which involve a combined delay line and high resistivity semiconductor structure.

Experiments on submicron pattern definition using an electron beam to expose suitable polymer films have been successful. Polymethylmethacrylate is at present the most promising material. Chemical etching and ion bombardment are two methods that are being evaluated as a means of etching the high resolution patterns.

Further evaluation and control of RF sputtering of silicon dioxide for capacitor and circuit isolation have been pursued, and yields have been high considering the temporary environment in which the work is performed.

The Mannplot automated artwork programs have been expanded further, and their documentation is nearly completed. A separate program to prepare data for Mannplot which has been assembled from the recently acquired digitizer is under way.

Application of these developmental efforts to specific Laboratory programs increased considerably during this reporting period, and we are currently processing 25 major tasks.

SOLID STATE
DIVISION 8

INTRODUCTION

This section summarizes the work of Division 8 from 1 February through 30 April 1969. A more detailed presentation is covered by the Solid State Research Report for the same period. The work formerly reported under Optical Techniques and Devices will henceforth appear in the Division 5, Optics, section.

P. E. Tannenwald
Acting Head, Division 8

DIVISION 8 REPORTS ON GENERAL RESEARCH

15 February through 15 May 1969

PUBLISHED REPORTS

Journal Articles*

JA No.			
3082	Symmetry of the Ground Level of a Hamiltonian	W. H. Kleiner T. A. Kaplan	J. Math. Phys. 10, 236 (1969)
3275	Descriptions of Outer d Electrons in Thiospinels	J. B. Goodenough	J. Phys. Chem. Solids 30, 261 (1969)
3286	Homogeneity Ranges and Te_2-Pressure Along the Three-Phase Curves for Bi_2Te_3(c) and a 55-58 at.% Te, Peritectic Phase	R. F. Brebrick	J. Phys. Chem. Solids 30, 719 (1969)
3300	Metallic Inclusions and Cellular Substructure in $Pb_{1-x}Sn_xTe$ Single Crystals	J. F. Butler T. C. Harman	J. Electrochem. Soc. 116, 260 (1969)
3304	Self-Modulation, Self-Steepening, and Spectral Development of Light in Small-Scale Trapped Filaments	T. K. Gustafson† J-P. Taran† H. A. Haus† J. R. Lifsitz† P. L. Kelley	Phys. Rev. 177, 306 (1969)
3311	Effects of Pressure on the Magnetic Properties of MnAs	N. Menyuk J. A. Kafalas K. Dwight J. B. Goodenough	Phys. Rev. 177, 942 (1969)
3312	Effect of the Molecular Interaction Between Anisotropic Molecules on the Optical Kerr Effect. Field-Induced Phase Transition	J. Hanus	Phys. Rev. 178, 420 (1969)
3317A	Fermi Surface and Optical Properties of Copper	G. F. Dresselhaus	Solid State Commun. 7, 419 (1969)
3326	Characterization of Phases in the 50-60 at.% Region of the Bi-Te System by X-Ray Powder Diffraction Patterns	R. F. Brebrick	J. Appl. Crystal. 1, 241 (1968)

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JA No.			
3335	Transport Equation for Interacting Fermions in Random Scattering Centers. I. A Quasiparticle Description in the Macroscopic and Low Temperature Limit	J.L. Sigel P.N. Argyres	Phys. Rev. 178, 1016 (1969)
3336	Epitaxially Grown Guard Rings for GaAs Diodes	C.M. Wolfe W.T. Lindley	J. Electrochem. Soc. 116, 276 (1969)
3345	Optical Properties of Mg_2Si, Mg_2Ge and Mg_2Sn from 0.6 to 11.0 eV at 77°K	W.J. Scouler	Phys. Rev. 178, 1353 (1969)
3348	Temperature Dependence of Raman Linewidth and Shift in α-Quartz	A.S. Pine P.E. Tannenwald	Phys. Rev. 178, 1424 (1969)
3350	The P-T Phase Diagram of InSb at High Temperatures and Pressures	M.D. Banus M.C. Lavine	J. Appl. Phys. 40, 409 (1969)
3365	Photoluminescence of Metals	A. Mooradian	Phys. Rev. Letters 22, 185 (1969)
3371	Bismuth Doped $Pb_{1-x}Sn_xTe$ Diode Lasers with Low Thresholds	J.F. Butler T.C. Harman	IEEE J. Quant. Electron. QE-5, 50 (1969)
3386	Transient and Steady State Thermal Self-Focusing	R.L. Carman* A. Mooradian P.L. Kelley A. Tufts	Appl. Phys. Letters 14, 136 (1969)
3387	Infrared Transmission, Magnetic Birefringence, and Faraday Rotation in EuO	J.O. Dimmock C.E. Hurwitz T.B. Reed	Appl. Phys. Letters 14, 49 (1969)
3411	Report on International Conference on Silicon Carbide	J.R. O'Connor	J. Cryst. Growth 5, 152 (1969)
3421	Nuclear Linewidth Measurements of Mn^{55} in Antiferromagnetic $CsMnF_3$ and $RbMnF_3$	R. Weber M.H. Seavey*	Solid State Commun. 7, 619 (1969)
3426	GaAs Schottky Barrier Avalanche Photodiodes	W.T. Lindley R.J. Phelan, Jr. C.M. Wolfe A.G. Foyt	Appl. Phys. Letters 14, 197 (1969)
3436	$Pb_2M_2O_{7-x}$ (M = Re, Ir, Re) – Preparation and Properties of Oxygen Deficient Pyrochlores	J.M. Longo P.M. Raccah J.B. Goodenough	Materials Res. Bull. 4, 191 (1969)
3445	Experimental Techniques in Raman Spectroscopy	A. Mooradian	SPEX Speaker Ramalogs 2 (1969)

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MS No.			
2039	Critical Phenomena in Heisenberg Models of Magnetism	H. E. Stanley	Chapter 14, Solid State Physics, Nuclear Physics and Particle Physics, I. Saavedra, Ed. (W. A. Benjamin, Inc., New York, 1968); Proc. 9th Latin American School of Physics
2228	Interpolation Methods for Phonon Spectra in Crystals	G. F. Dresselhaus M. S. Dresselhaus	Intl. J. Quant. Chem. IIS, 333 (1968)
2307	Diffusion and Convection in Vapor Crystal Growth	T. B. Reed W. J. LaFleur A. J. Strauss	J. Cryst. Growth 3, 115 (1968)
2336	Light Scattering from Plasmons in Semiconductors	A. L. McWhorter	Proc. International Advanced Summer Physics Institute (Plenum, New York, 1969)

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UNPUBLISHED REPORTS

Journal Articles

JA No.			
3173A	Statistical Thermodynamics of Nonstoichiometry in Non-Metallic Binary Compounds	R. F. Brebrick	Accepted by J. Solid State Chem.
3281	Crystallographic and Magnetic Properties of Perovskite and Perovskite-Related Compounds	J. B. Goodenough J. M. Longo	Accepted as a chapter in Landolt-Bornstein Tabellen (Springer-Verlag, Berlin)
3369	Inversion Asymmetry and Warping Induced Interband Magneto-Optical Transition in InSb	C. R. Pidgeon* S. H. Groves	Accepted by Phys. Rev.
3400	Magnetoreflection Studies in Arsenic	M. Maltz M. S. Dresselhaus	Accepted by Phys. Rev.
3412A	Experimental Comparison of Hartree-Fock and Slater Exchange Potentials in Aluminum from the Charge Density Point of View	P. M. Raccah V. E. Henrich	Accepted by J. Quant. Chem.
3417	Space-Time Symmetry Restrictions on Transport Coefficients. III. Thermogalvanomagnetic Coefficients	W. H. Kleiner	Accepted by Phys. Rev.
3423	Brillouin Scattering Study of Acoustic Attenuation in Fused Quartz	A. S. Pine	Accepted by Phys. Rev.

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JA No.			
3437	The Effect of Pressure and B-Cation Size on the Crystal Structure of $CsBF_3$ Compounds (B = Mn, Fe, Co, Ni, Zn, Mg)	J. M. Longo J. A. Kafalas	Accepted by J. Solid State Chem.
3441A	Magnetoreflection Studies on the Band Structure of Bismuth-Antimony Alloys	E. J. Tichovolsky J. G. Mavroides	Accepted by Solid State Commun.
3442	Effects of Light on the Charge State of InSb-MOS Devices	W. E. Krag R. J. Phelan, Jr. J. O. Dimmock	Accepted by J. Appl. Phys.
3447	Polymorphism in Selenospinels – A High Pressure Phase of $CdCr_2Se_4$	M. D. Banus M. C. Lavine	Accepted by J. Solid State Chem.
3449	Magnetoemission Experiments in $Pb_{1-x}Sn_xTe$	J. F. Butler	Accepted by Solid State Commun.
3460	Metallic Oxides	J. B. Goodenough	Accepted as a chapter in Progress in Solid State Chemistry (Pergamon Press, New York)
3463	Temperature and Compositional Dependence of Laser Emission in $Pb_{1-x}Sn_xSc$	T. C. Harman A. R. Calawa I. Melngailis J. O. Dimmock	Accepted by Appl. Phys. Letters
3468	Magnetospectroscopy of Shallow Donors in GaAs	G. E. Stillman C. M. Wolfe J. O. Dimmock	Accepted by Solid State Commun.

Meeting Speeches*

MS No.			
1954E	Conceptual Phase Diagram for Outer d Electrons in Solids	J. B. Goodenough	Societe Chimique de France, Paris, 14 March 1969
2338A	Meaning of an Anomaly in the X-Ray Scattering of ZnSe	P. M. Raccah	Seminar, Boston College, 19 March 1969
2378A	Exact Solution for a Linear Chain of Isotropically Interacting Classical Spins of Arbitrary Dimensionality	H. E. Stanley	American Physical Society, Philadelphia, Pennsylvania, 24-27 March 1969
2471	Spin-Space Group Analysis of $^4A_2 \rightarrow {}^2E$ Excitons in Cr_2O_3	J. W. Allen	

* Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
2472	Photoluminescence Due to Isoelectronic Te Traps in $Zn_{1-x}Cd_xS$ and $ZnS_{1-y}Se_y$ Alloys	G. W. Iseler A. J. Strauss	
2473	Magneto-Optical Investigation of Bi-Sb Alloys	E. J. Tichovolsky J. G. Mavroides	
2475	Inelastic Light Scattering from Semiconductor Magnetoplasmas	F. A. Blum	
2476	Polaron Zeeman Effect in AgBr	R. C. Brandt P. P. Crooker D. M. Larsen G. B. Wright	
2477	Temperature Dependence of Laser Emission in $Pb_{1-x}Sn_xSe$ Diodes in the Range $0 \leq x \leq 0.3$	A. R. Calawa I. Melngailis T. C. Harman	
2480	High Temperature Conductivity and Hall Coefficient of Zinc Telluride	F. T. J. Smith	
2482	Shubnikov-de Haas Measurements in $Pb_{1-x}Sn_xTe$	I. Melngailis T. C. Harman J. G. Mavroides J. O. Dimmock	American Physical Society, Philadelphia, Pennsylvania, 24-27 March 1969
2483	Linear Wavevector Shifts in the Raman Spectrum of α-Quartz	A. S. Pine G. F. Dresselhaus	
2484	Effect of Deviations from Stoichiometry on Lattice Parameters of $Pb_{1-x}Sn_xTe$ Alloys	A. J. Strauss	
2485	Magnetic Energy Level Structure and Perturbation Theory	M. S. Dresselhaus P. R. Schroeder*	
2486	Efficient Doping of GaAs by Se^+ Ion Implantation	A. G. Foyt J. P. Donnelly W. T. Lindley	
2487	Reflectance of EuO from 0.5 to 11.0 eV	W. J. Scouler J. Feinleib J. O. Dimmock T. B. Reed	
2488	Infrared Absorption in Gd-Doped EuO	C. E. Hurwitz M. R. Oliver J. O. Dimmock T. B. Reed	

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Division 8

MS No.			
2493	Ion Implanted GaAs Avalanche Photodiodes	W. T. Lindley J. P. Donnelly A. G. Foyt R. J. Phelan, Jr.	American Physical Society, Philadelphia, Pennsylvania, 24-27 March 1969
2420F	Light Scattering from Semiconductors	A. Mooradian	Seminar, Harvard University, 19 February 1969
2452	Free Energy of Formation of Binary Compounds – An Atlas of Charts for High Temperature Chemical Calculations	T. B. Reed	American Chemical Society, Minneapolis, Minnesota, 17 April 1969
2465	Liquidus Surface in the Zn-Cd-Te Ternary System	J. M. Steininger A. J. Strauss	Electrochemical Society, New York, 9 May 1969
2466	The Role of Oxygen Pressure in the Control and Measurement of Composition in 3d Metal Oxides	T. B. Reed	Second Solid State Chemistry Conference, Scottsdale, Arizona, 21-25 April 1969
2506	Structural, Electrical and Magnetic Properties of Vacancy-Stahilized Cubic TiO and VO	M. D. Banus T. B. Reed	
2515	Evidence for a Continuous Sequence of Phases in the Bi-Te System	R. F. Brebrick	
2476A	Polaron Effects in Silver Bromide	R. C. Brandt	Seminar, University of Illinois, 9 May 1969
2499	The Effect of Pressure and B-Cation Size on the Crystal Structure of $CsBF_3$ Compounds (B = Mn, Fe, Co, Ni, Zn, Mg)	J. A. Kafalas J. M. Longo	Symposium on Crystal Structure at High Pressure, Seattle, Washington, 24-28 March 1969
2509	X-Ray Diffraction Studies on Cd_3As_2 and Zn_3As_2 at High Pressure	M. D. Banus M. C. Lavine	
2499A	Effect of High Pressure and Ion Size on Structure and Properties of ABX_3 Compounds	J. M. Longo	Technical Lecture, Naval Weapons Center, China Lake, California, 31 March 1969
2506A	Structural, Electrical and Magnetic Properties of Vacancy-Stahilized Cubic TiO and VO	M. D. Banus T. B. Reed	Seminar, Battelle Northwest Laboratories, Richland, Washington, 28 March 1969
2513	Ion Implantation in GaAs	A. G. Foyt	Seminar, Bell Telephone Laboratories, Murray Hill, New Jersey, 24 April 1969

MS No.			
2527	Comparison of Experimental and Theoretical Charge Densities for Si, Ge, and ZnSe	P. M. Raccah R. N. Euwema* D. J. Stuckel* T. C. Collins*	American Physical Society, Washington, D. C., 28 April – 1 May 1969
2528	Light Scattering in Semiconductors	A. Mooradian	German Physical Society, Munich, Germany, 19 March 1969
2538	Cyclotron Waves and Landau Parameters	A. R. M. Wilson	Seminar, Bell Telephone Laboratories, Murray Hill, New Jersey, 5 February 1969
2539	The Deformation Potential in Silicon	W. E. Krag	Seminar, Boston College, 12 March 1969
2540	Fermi Surface and Optical Properties of Metals	G. F. Dresselhaus	Seminar, University of Maryland, 6 March 1969
2541, 2541A, 254IB	Derivation of a Quasiparticle Transport Equation for an Impure Fermi Liquid at Low Temperatures	J. L. Sigel	Seminar, Brown University, 6 March 1969; Seminar, Northeastern University, 11 March 1969; Seminar, University of Maryland, 21 April 1969
2543	Optical Imaging and Storage with MOS Structures	R. J. Phelan, Jr.	New England Chapter, Thin Film Division, American Vacuum Society, M. I. T. Lincoln Laboratory, 5 March 1969
2554, 2554A	Spectroscopy and Structure of Some Inorganic Solids	H. M. Kasper	Seminar, University of Michigan, 9 April 1969; Seminar, Arizona State University, 19 April 1969
2570	Ion Implantation in Semiconductors	J. P. Donnelly	Seminar, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 17 April 1969
2571	Ion Implantation in Compound Semiconductors	A. G. Foyt	Seminar, M. I. T., 18 April 1969
2587	Polaron Effects in Solids	D. M. Larsen	Seminar, M. I. T., 9 May 1969

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SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

Spectral measurements in the frequency range from 10 to 130 cm^{-1} in magnetie fields from 0 to 30 kG of the far-infrared photoconduetivity due to shallow donors in GaAs are reported. These measurcments reveal peaks due to the isolated (1s → 2p) and (1s → 3p) transitions in addition to a broad continuum at higher energy. From the energy of these peak transitions and their splitting in a magnetic ficld we obtain a donor ionization cnergy of 5.86 ± 0.02 meV and an effeetive mass of 0.0665 ± 0.0005 m_o.

Electroluminescent metal-insulator-semieonduetor (MIS) diodes have been fabrieated using p-type ZnTe. The insulating layer was produced by bombarding the ZnTc with a dose of 5×10^{14} protons/cm^2 which at an energy of 400 keV produees a high resistivity region approximately 5 μ deep. Broad red eleetroluminescence was observed in forward bias breakdown with a quantum efficieney in exeess of 2×10^{-3} at 77°K and 2×10^{-4} at 300°K.

Effieient doping of GaAs by ion implantation has bcen obtained using Se^+ ions. For a Se^+ dose of $3 \times 10^{12}/cm^2$ implanted at 400 keV, a peak earrier concentration of $2 \times 10^{17}/em^3$ occurred at a depth of 750 Å, with a standard deviation of 500 Å. Integration of the excess carrier concentration caused by the implantation indicates that for this ion dose more than 50 percent of the implanted ions are electrieally aetive. For larger doses, the doping effieiency decreases and the carrier concentration approaches a limiting value of approximately $10^{19}/cm^3$.

II. MATERIALS RESEARCH

X-ray diffraction mcasurements on metal- and tellurium-saturated $Pb_{1-x}Sn_xTc$ alloys have shown that deviations from stoichiometry have a marked effect on the lattice parameters of alloys containing more than about 50 mole percent SnTe. Thc results are consistent with published data which show that Vegard's law is obeyed over the whole composition range from PbTe to SnTe by alloy samples with sufficiently small deviations from stoichiometry.

The Hall coefficient and resistivity of undoped ZnSe single crystals have been measured at temperatures between 650° and 1000°C and at controlled zinc vapor pressures between 5 and 1000 torrs. The results show that at the temperatures and pressurcs invcstigated the elcctrical propertics are determined by the eoncentration of a singly ionized native donor defcct.

Photoluminescence due to tellurium substituted for sulfur or selenium has been obscrved at 4.2°K over thc whole composition range of the ZnS-CdS and ZnS-ZnSe alloys. In both systems, the variation of the photoluminescence energy with composition is consistent with the isoelectronic trap model, according to which the trapping energy should becomc greater with increasing difference in electronegativity between the isoelectronic dopant and the host atom for which it substitutes.

Measurements of lattice parameter, density, electrical resistivity, Seebeck eoeffieient, and magnetie susceptibility have been made on a large number of single-phase samples of cubic

TiO_x and VO_x with compositions spanning the extremely wide homogeneity range of each compound. Resistivity data for VO_x between 77° and 300°K fail to confirm the metal-semiconductor transition at about 120°K reported in the literature, but indicate that sufficiently oxygen-rich samples are probably semiconductors over the entire temperature range studied.

The compounds $Sr_4Ir_3O_{10}$ and $Sr_3Ir_2O_7$ have been synthesized at high pressures by reacting the appropriate amounts of Sr_2IrO_4 and IrO_2 at 1000°C. These compounds are the intermediate members in the series of compounds with the general formula $Sr_{1+x}IrO_{3+x}$ ($x = 0, \frac{1}{3}, \frac{1}{2}, 1$) whose structures consist of a number of perovskite units (ABX_3) interleaved with rock-salt layers (AX).

III. PHYSICS OF SOLIDS

Study of the band structure of the magnetic semiconductor EuO has continued. Splittings in the reflectivity spectrum on cooling to below the Curie point have been observed and interpreted as direct evidence for a spin-split conduction band.

An investigation of the magnetic interactions in the ferromagnetic conducting alloys $CoS_{2-x}Se_4$ has been initiated. Preliminary measurements in the magnetic transition region for $x = 0.1$ and 0.2 have raised some question regarding the order of the phase transition; it is hoped that differential thermal analysis may resolve this point. Concurrent with this experimental work, a theoretical study was carried out of the spin configuration which minimizes the classical Heisenberg exchange energy in the fcc lattice with first and second neighbor interactions. Our results are in contradiction to the spin configurations of CoSSe and $CoSe_2$ proposed by Adachi, et al., from neutron diffraction. If the latter configurations are correct, then there must be significant contributions to the energy from other than Heisenberg interactions.

Investigation of the local stability of the conical spiral spin configuration in normal cubic spinels shows that the spiral which gives good agreement with experiment for $CoCr_2O_4$ is actually unstable for the estimated values of the nearest-neighbor A-A, A-B, and B-B, and more-distant-neighbor B-B exchange interactions. The results demonstrate the existence of a new, previously unimagined configuration having nonzero Fourier components associated with more than one member of the $\vec{k} = (h, h, 0)$ family, a configuration which appears to be more complicated than an epicone spiral.

Space-time symmetry restrictions on the thermogalvanomagnetic coefficients occurring for the magnetic field $H \neq 0$ have been examined further. Several previous tables have been supplemented.

The high-resolution thermal Brillouin scattering technique has been used to study the temperature dependence of the hypersonic (3- to 5-GHz) velocity and attenuation in liquid nitrogen along the saturated vapor line from the triple point to the normal boiling point. Since both the velocity and attenuation results agree with previous measurements at megahertz frequencies, the acoustical dispersion due to the 2-GHz internal molecular vibration frequency is completely negligible.

Light emission has been observed from optically excited gold, copper and gold-copper alloys. This emission, which involves states near the Fermi level, is consistent with optical absorption data.

Further work on light scattering by single-particle excitations in GaAs indicates that, although most of the anomalously large cross sections can be explained by spin-density fluctuations,

the large temperature-dependent cross section observed in high density samples (with incident and scattered polarization vectors parallel) requires a different mechanism. A study of resonant enhancement effects indicates that, despite the very small fluctuations in total charge density, fluctuations in the occupancy of electronic states can account for the parallel polarization cross section.

The theory of thermal self-trapping by CW laser beams in solids has been applied to a calculation of the half-power diameter in four different materials. Where experimental results exist (in two types of glass), the theory agrees reasonably well.

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13. ABSTRACT

This Quarterly Technical Summary covers the period from 1 February through 30 April 1969. It consolidates the reports of Division 2 (Data Systems), Division 4 (Radar), Division 5 (Optics), Division 7 (Engineering), and Division 8 (Solid State) on the General Research Program at Lincoln Laboratory.

14. KEY WORDS

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